GMI Footprint Changes Due to 35 km Altitude Boost

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Simplified Footprint Definition and Detailed Aspects

- A simple Instantaneous Field-Of-View (IFOV) definition of a beam footprint is given by the projection of a fixed beamwidth (cone) onto a flat surface as an ellipse.
  - This IFOV definition is used in calculation of some results that follow
- In practice a microwave receiver antenna pattern beam is a complex shape with side-lobes and some frequency dependence for the radiometer sensitivity. Details for GMI are in the instrument data book.
- In addition, the IFOV is integrated over a time period as the beam sweeps across the surface for satellite observations. For the GMI 3.6 milliseconds of integration time, the beam moves over 5 kilometers along the scan from the GMI spin. The integrated signal is called the Effective Field-of-View (EFOV).

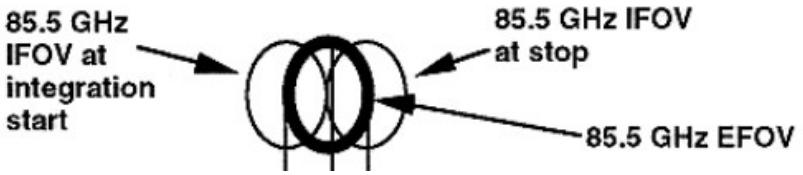
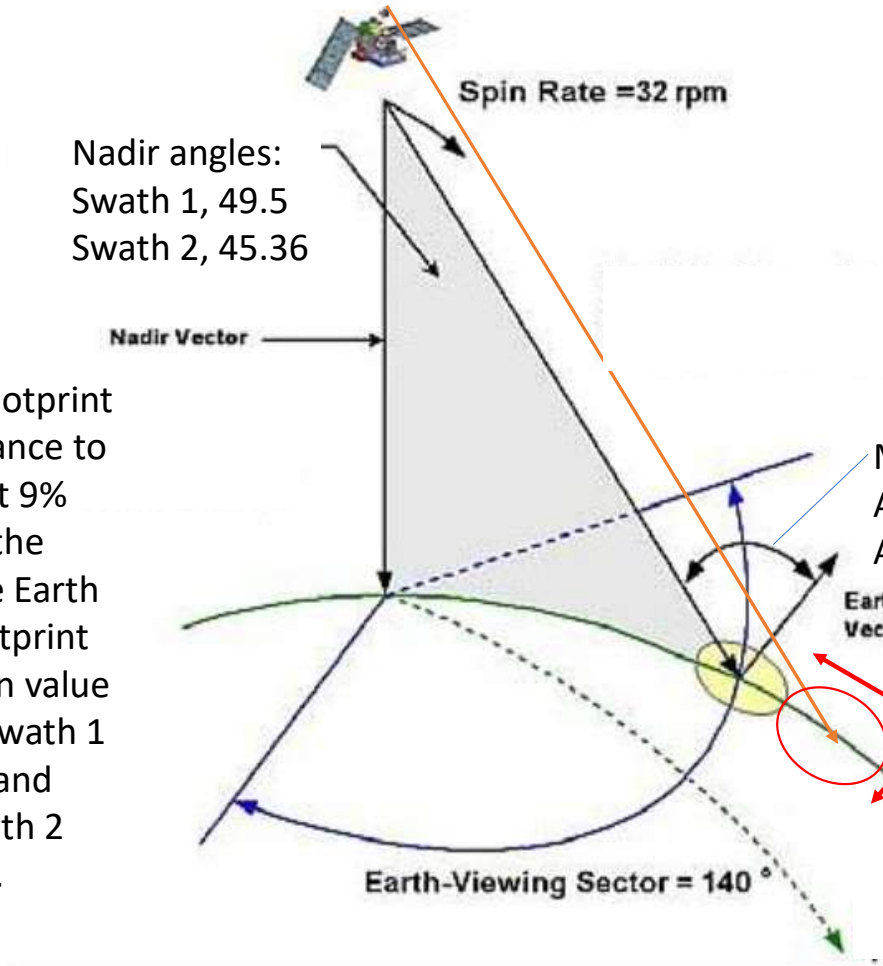


Illustration of IFOV and EFOV from Kummerow et.al, The Tropical Rainfall Measuring Mission (TRMM) sensor package, June 1998..

Schematic of Altitude Boost Impact on Footprint Size (not to scale)



The main impact on the footprint size is from increased distance to the surface, which is about 9% farther away. Because of the curvature of the Earth, the Earth Incidence Angle at the footprint center increases by a mean value of about 0.39 degrees in Swath 1 (low frequency channels) and about 0.34 degrees in Swath 2 (high frequency channels).

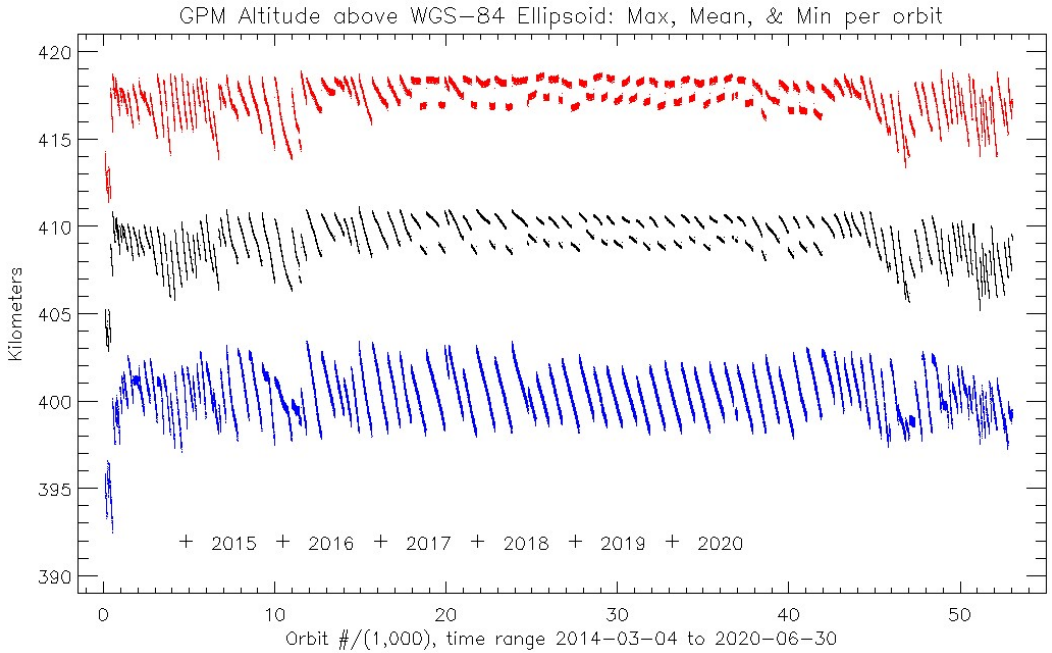
Mean Earth Incidence (Zenith) Angles
At 407 km, Swath 1: 52.8°, Swath 2: 49.2°
At 442 km, Swath 1: 53.2°, Swath 2 :49.5°

Radial ~9.7 % size increase

Axial ~9.1 % size increase

Mean Ground Track Speed:
~ 7.22 km/sec pre-boost
~ 7.16 km/sec post-boost

The actual geodetic height around the surface varies around each orbit, and so the footprint size varies proportionally by about 5% each orbit. The Maximum, Mean, and Minimum altitude over the first 8 years of the mission are shown in the plot below. The actual mean altitude has generally been a little higher than the 407 kilometers referenced in the GMI design specifications.



The planned range of operating altitudes pre- and post-boost are shown in the table below. The "Proportional Height Increase" gives the increase size in pixels at nadir as a first order approximation. The pixels size increases are a little larger for the GMI beams due to Earth curvature effects.
We estimate the GMI changes by adding 35 km relative to the GMI Spec value of 407 km.

GPM Geodetic Height Range	Pre-Boost	Post-Boost +35	Proportional Height Increase
Maximum	419	454	8.35 %
Median	408	443	8.58 %
GMI Spec	407	442	8.60 %
Minimum	397	432	8.82 %

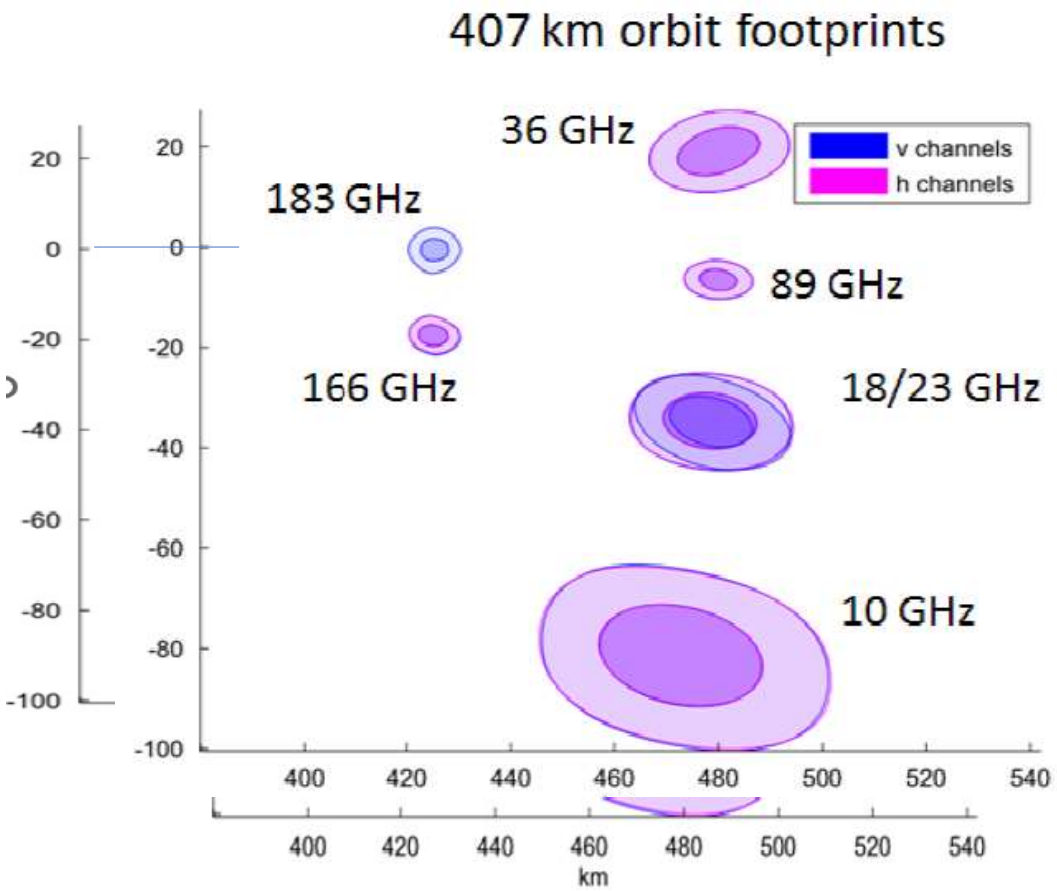
Instantaneous Field of View (IFOV) footprint per channel computed from V polarization Half-Power Beam-Width (HPBW) above 6378 radius Earth. Very small differences in measured beamwidths and off-nadir angles between V- and H-pol do not significantly impact the footprint size.

Axial x Radial in km per Channel	10.65v/h	18.7v/h	23.8v	36.64v/h	89v/h	166v/h	183±3/7v
IFOV @ 407 km (km)	19.2 x 31.8	11.0 x 18.1	9.5 x 15.7	9.2 x 15.2	4.3 x 7.0	4.0 x 6.1	3.9 x 5.9
IFOV @ 442 km (km)	21.0 x 35.0	12.0 x 19.9	10.4 x 17.3	10.0 x 16.7	4.6 x 7.7	4.3 x 6.7	4.2 x 6.5

Taking the V-pol footprint size from GMI Handbook Rev H pages 74-80. HPBW footprint size for 407 km and 635 km altitudes. We calculate the IFOV at 442 km assuming a linear relationship between the 407 and 635 km altitudes for the axial and radial footprint span.

Axial by Radial in km per Channel	10.65v/h	18.7v/h	23.8v	36.64v/h	89v/h	166v/h	183±3/7v
IFOV @ 407 km (km)	19.5 x 31.5	11.1 x 17.9	9.6 x 15.7	9.1 x 15.1	4.2 x 7.1	4.2 x 5.7	4.4 x 5.3
IFOV @ 442 km (km)	21.3 x 34.9	12.1 x 19.8	10.5 x 17.4	9.9 x 16.7	4.6 x 7.9	4.6 x 6.3	4.8 x 5.9

The actual IFOV shapes are not exactly ellipses and vary a bit in the V and H channels, as illustrated in this figure from GMI engineering data book which maps the ½ power and 90% power beam shapes projected to the ground, with beams shown separated by the feedhorns that the reflector rotates over top of in turn.



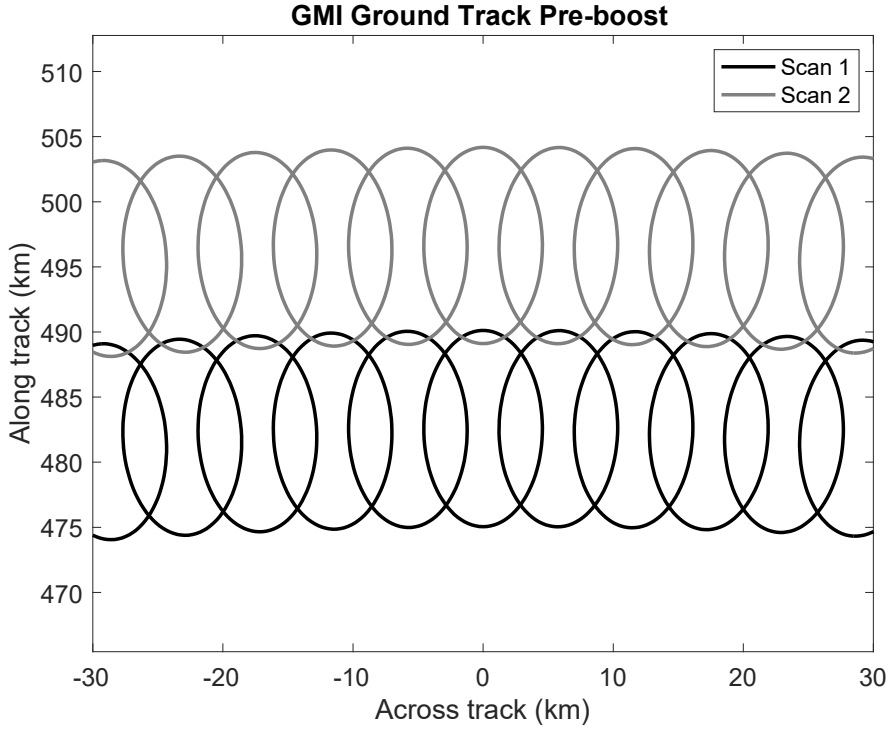
Approximate scale change in ground footprint sizes after boost shown in kilometers.

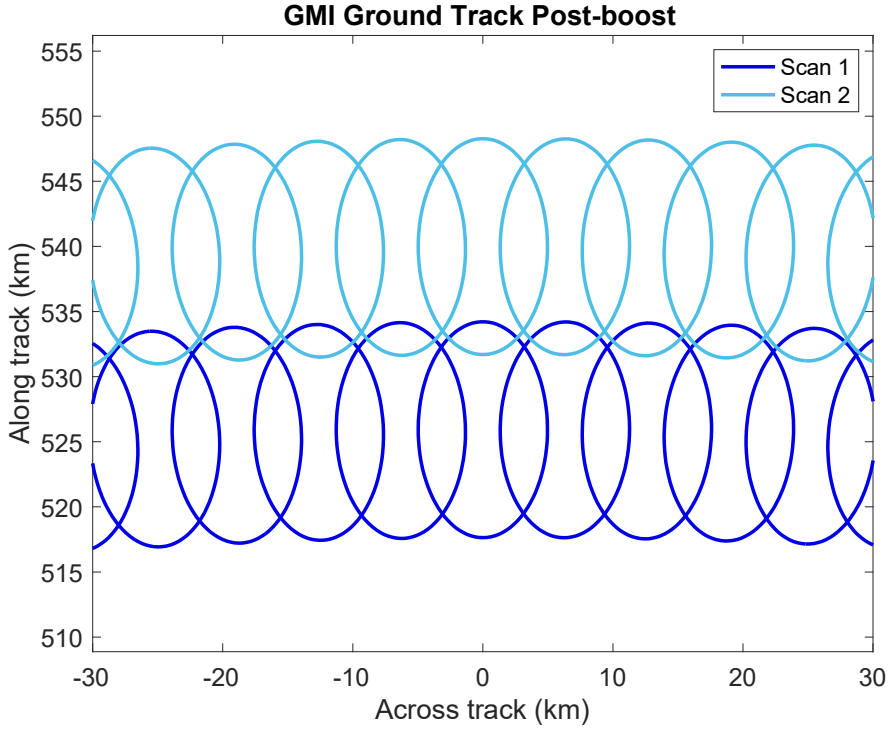
GMI Ground Track: 37 GHz channel (in Swath 1)

Pre-boost (407 km altitude) swath width: 930 km

Post-boost (442 km altitude) swath width: 1015 km

Figures show comparison of footprints from two adjacent scan lines at the center of the scan





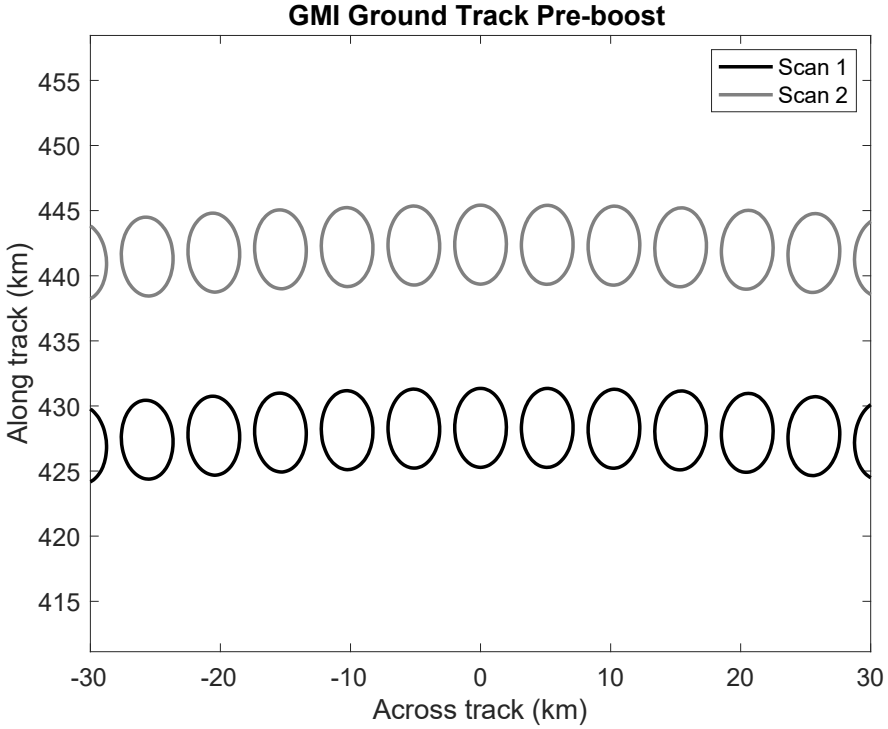
Another aspect of the footprint changes results from the spacing of the observed pixels at the new altitude. Beam centers are about 9 percent further apart along the scan. Meanwhile in the along—track direction the footprints are about 0.8 percent closer from one scan to the next because the orbit period is longer and the ground track speed is slightly slower at the higher altitude.

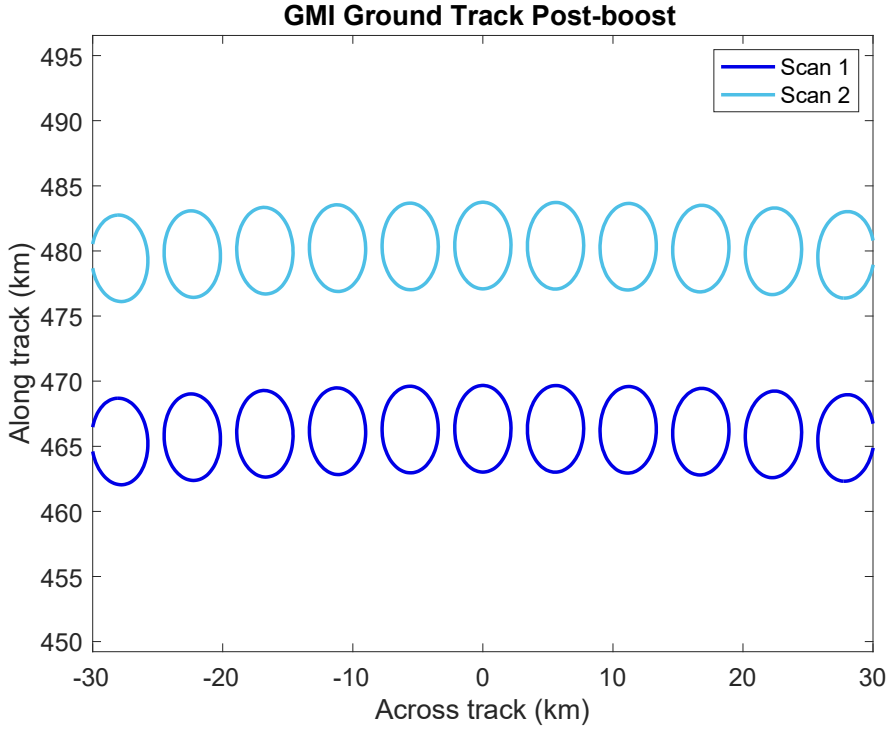
GMI Ground Track: 166 GHz channel (in Swath 2)

Pre-boost (407 km altitude) swath width: 825 km

Post-boost (442 km altitude) swath width: 899 km

Figures show comparison of footprints from two adjacent scan lines at the center of the scan





The high frequency channel footprints do not overlap like the lowest frequency channel footprints which are bigger. Note that about 11 pixels fit in +/- 30 km across the middle of the scan a1t the new altitude for Swath 2, while about 12 pixels fit in that 60 km distance at the lower altitude. The previous slide shows Swath 1 fits 10 or 11 pixels within the 60 km due to the wider scan radius.